

# The manual transport of load and the commercial aviation in Brazil

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**Abstract.** The Brazilian commercial aviation industry has grown strongly in the last decades, increasing passenger capacity and operational safety. While several studies focus on flight safety and passenger comfort, few are dedicated to the manual transport of loads. Although apparently this sector has low relevance, every year nearly 9% of their workers are injured. It is estimated that these injuries cost more than 10 million dollars a year to the companies involved. This study assesses quantitatively the risk of injury on employees. NIOSH method was used to evaluate the possibility of injury in different tasks. Factors such as the pace of activity, horizontal and vertical displacement, and asymmetries were evaluated during loading and unloading of luggage. This study showed that the frequency of repetitions of loading was excessive in all cases analyzed. However, the use of conveyors reduced the risk of employee injury, reducing this possibility to acceptable levels. The study shows that simple measures can help reduce the number of injuries and hence the cost that this entails.

Keywords: manual transport of loads, operational cost, civil aviation

## 1. Introduction

Aviation as a whole, and passenger transport in particular, have evolved greatly in many ways over the last fifty years. The time that flying was for few lucky people – or for the brave – has passed. To travel by plane was once considered an adventure becoming later a luxury for few. Nowadays the plane became a means of transport like many others, flying has become a habit and a necessity for many people. The ability to carry passengers and loads grew, travel time was reduced, and safety increased.

Despite all changes observed in aircrafts, some activities have modified very little in aviation. The cargo transportation on the ground, critical step for the proper functioning of airline companies, suffered comparatively little change. Although seemingly simple, this task proves crucial to the whole structure of the airline company, avoiding huge setback when baggage and passengers do not arrive together at the destination.

A close observation of the picture engraved on the wall of the central hall of the Santos Dumont airport

in Rio de Janeiro (Figure 1) reveals curious aspects. The image depicts the courtyard of the airport on a typical day during the 1930s and 1940s. It is possible to observe the aircraft model Douglas DC-3, passengers impeccably dressed, and baggage handlers working. While aircraft and clothing changed dramatically since then the manual transport of loads changed little (Figure 2).



Figure 1

Reproduction of part of the painting shown in the lobby of the Santos Santos Dumont Airport representing the daily life of an airport during the 1940s.

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Figure 2:  
Workers on the ground unloading passengers' luggage.

## 2. Relevance of the topic

Ergonomic studies related to aviation have focused on improving the driver's commands and passenger's comfort [1,3,4]. However, a small number of studies are devoted to the ground manual transport of loads [2, 5, 6]. Even if this sector is not the focus of most studies, every year it causes a large number of injuries in their workers.

In a 1981 ARTEX (International Air Transport Executive) study, the National Safety Council of America committee showed that only in the US more than 300 back injuries were registered annually in employees of this sector. For Dell (1998), over 85% of these injuries can be directly related to the baggage loading. Every year, nearly 9% of the workers suffer some kind of back problem. However, the low investment in this activity is not penalizing only the workers: it is estimated that these injuries costs more than 10 million US dollars a year to airline companies [2].

The rate of employees with back injuries in the civil aviation injuries is extremely high worldwide. In 2002 this industry listed second in the US Bureau of Labor Statistic ranking in number of injuries, surpassing even the mining sector [6].

Several ergonomic studies associate back and shoulder injuries with the manual transport of loads, especially when it involves lifting and lowering, repetitive movements, and the work in places where the posture is not adequate [5]. This is precisely the scenario found in the daily work of airline porters.

Dell [2] conducted interesting research interviewing 156 baggage handlers from ten worldwide airline companies and two specialized ground baggage han-

dling companies. The employees filled a survey with several questions about the routine activities and possible back injuries. From the 156 interviewed workers, 148 were male with in average 36 years old.

When asked whether or not a given task could be associated with back injury, 84% of employees indicated the direct transfer of luggage from the cart into the aircraft as a possible cause and 66% believe that these injuries may result from the luggage transfer from the cart to the conveyor. Over 70% of the respondents had experienced back injuries caused by work and over half of these lesions were recurrent, often reducing their ability to work. Even more worrying, a significant share of workers stated that suffer daily pain.

When asked about which technological advances employees believe to be the most effective in preventing injuries, 70% of the respondents stated that the improvement in equipment used in cargo handling and the use of conveyors could help minimize the risks. For almost 90% of the surveyed, the simple improvement on training would help, while for 76% the better distribution of working hours would also promote an effective improvement. The decreasing rate of the luggage loading is, for 67% of the respondents, a relevant factor in reducing injuries.

Thus, the importance of this present scenario should require special attention from the airline companies, government, and society. This study is dedicated to assess quantitatively some of the hypotheses raised by the interviewed workers in Dell [2]. The methodology proposed by NIOSH (National Institute for Occupational Safety and Health) will be used to evaluate the possibility of injury faced by workers in different tasks. Both the rate of the activity and the use or not of conveyors will be evaluated.

## 3. Methodology

### 3.1. Work situations analyzed

Five typical luggage loading and unloading cases at the Santos Dumont Airport in Rio de Janeiro were analyzed. The airport, located in Rio de Janeiro downtown serves local domestic flights, being the short distance shuttle between Rio and São Paulo responsible for most of its activity.

The following cases were analyzed:

a) Case 1:

Flight originated in São Paulo (Congonhas Airport).

Landing date and time: Friday, 8:02 a.m.

Aircraft: Airbus A319.

Task: Luggage unloading.

b) Case 2:

Flight originated in São Paulo (Congonhas Airport).

Landing date and time: Friday, 8:56 a.m..

Aircraft: Airbus A319.

Task: Luggage unloading.

c) Case 3:

Flight originated in São Paulo (Congonhas Airport).

Landing date and time: Friday, 8:08 a.m..

Aircraft: Boeing 737-800.

Task: Luggage unloading.

d) Case 4:

Flight originated in Rio de Janeiro with destination São Paulo (Congonhas Airport)

Departure date and time: Friday, 08:51 a.m..

Aircraft: Boeing 737-800.

Task: Luggage loading.

e) Case 5:

Flight originated in Rio de Janeiro with destination Uberlândia.

Departure date and time: Friday, 08:44 a.m..

Aircraft: Embraer 145

Task: Luggage loading.

### 3.2. NIOSH method for manual shift of loads.

The cases were analyzed based on the sequence of photographs that recorded in detail the movements made by workers while performing the tasks. The NIOSH method for the manual shift of loads, also called “NIOSH equation” [7], is a widely used tool to quantify injury risks. In addition, these results help identify solutions to reduce the physical stress associated with the activity.

First, it is estimated the RWL factor or “Recommended Weight Limit,” Eq (1). This equation is based on the multiplication of six factors, each associated with a particular feature of the task.

$$RWL = LC.HM.VM.DM.AM.FM.CM \quad (1)$$

The terms that constitute this equation are means of the horizontal distance between the employee and the load (HM), vertical distance (VM), total walking distance (DM), body torsion (AM), rate of repetition of the task (FM), and the quality of handling of the object to be transported (CM). LC is the load constant equal to 23kg. The more severe the task per-

formed the lower are the values assigned to terms, resulting in a lower RWL.

LI, or “Lifting Index,” is then calculated from the RWL. LI, obtained from Eq. (2), provides an estimate of the level of physical stress associated with a given task of lifting loads manually.

$$LI = \text{Load Weight} / \text{RWL} \quad (2)$$

The higher the LI, the smaller the segment of workers capable of performing the task without suffering any injury. Thus, two or more procedures to accomplish the same task can be compared to the possibility of causing musculoskeletal injuries on employees. Knowing that a significant fraction of employees involved in the ground manual transport of loads suffer or will suffer such injuries and that this represents an enormous cost to the companies involved, to reduce the LI parameter on routine activities becomes of both social and business interest.

According to the NIOSH method, these tasks represent a higher risk of injuries – specially back injuries – when LI is greater than 1.0. The risk becomes extremely high when LI exceeds 2.0. Thus, it is recommended to design tasks in order to obtain LI lower than 1.0 [7].

## 4. Results

### 4.1. Case 1

This case examines luggage unloading from an Airbus A319, whose flight originated in São Paulo. Unlike the other cases here analyzed, these workers use conveyors to assist the cargo transportation between the aircraft and the baggage cart. An employee located inside the aircraft compartment puts the bags over the conveyor while another employee removes the bags and distribute them on the cart. This study focuses on this second employee. Below, the sequence of eight images (Figures 3 a, b, c) illustrate the movement made by the employee during the shift of bags over the cart.

The time spent in transporting each bag was of 2.42 seconds, needing another 2 seconds to return to the starting position next to the conveyor. Thus, the employee is able to repeat the cycle 13 times per minute, a rate considered very high according to the NIOSH method [7]. This fact in itself indicates high risk of injury. The parameter “FM” from Eq (1) represents the rate of repetitions of the task. For a

frequency of 13 repetitions per minute, this parameter is zero. It is observed that, mathematically, besides that it annuls the influence of all other factors involved, this would lead to a zero RWL and a infinitely large LI. The risk of injury for this scenario becomes evident.

To allow a more detailed study of each factor that make up Eq (1), not limited to the assessment of frequency, I chose to initially ignore the variable FM. It was also assumed that the weight of each checked bag (LC) is equal to the maximum allowed by airlines on domestic flights (23kg) and that the capability of handling every luggage (CM) is good.

RWL and LI values calculated for origin and destination are shown in Table 1. Although the baggage unload is being performed using the conveyor, the physical effort done by the worker imposes high risk to his health as indicated by the LI value previously calculated. It should be once more emphasized that this value was calculated without considering the number of repetitions per minute. That is, the possibility of injury would be even higher if the frequency of repetitions were contemplated.

Ignoring the FM parameter, among the remaining terms in Eq. (1), HM and VM showed the greatest influence on the outcome. To reduce the HM the em-

ployee should be positioned closer to the load. However, this position is not favored given the fact that the employee is standing over the cart. If he was on the ground he would be able to position one foot over the vehicle, closer to the load, reducing his horizontal displacement (HM). This position would also avoid the need to bend too much over the luggage to catch it or to put it on its destination, reducing also the vertical displacement (VM). Although this position is positively seen from the NIOSH method point of view, when positioning himself on the ground the employee would have more difficulty to distribute the bags evenly over the entire surface of the cart. Probably, this difficulty that lead the worker to position himself over the cart.

#### 4.2. Case 2

The task developed in this case is similar to Case 1, meaning, the baggage unloading from an Airbus A319. However, in this case it was carried out without the help of a conveyor. The employee must then stand over the cart and stretch his arms in order to reach the bags inside the aircraft compartment (Figure 4).



Figure 3 (a)

Baggage unloading from Airbus A319 using a conveyor.

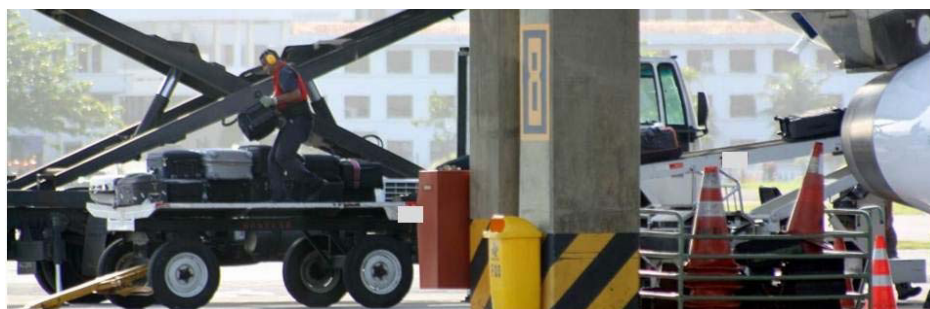


Figure 3 (b)



Figure 3 (c)

Table 1  
RWL and LI indexes for the analyzed cases disregarding the frequency of liftings.

	<b>RWL Origin</b>	<b>RWL Destination</b>	<b>LI Origin</b>	<b>LI Destination</b>	<b>Aircraft</b>	<b>Task</b>
<b>Case 1</b>	9.39	10.69	2.45	2.15	Airbus 319	Unload
<b>Case 2</b>	6.81	9.30	3.38	2.47	Airbus 319	Unload
<b>Case 3</b>	11.46	10.69	2	2.15	Boeing 737	Unload
<b>Case 4</b>	15.62	10.05	1.47	2.28	Boeing 737	Load
<b>Case 5</b>	6.72	0	3.42	+inf	Embraer 145	Load

The LI values found in this case are significantly higher than those observed in Case 1, especially for the origin. The vertical displacement at the origin is greatly increased, contributing strongly to the deterioration of the parameter LI (Table 1). Thus, becomes evident that using the conveyor during the baggage unloading it is possible to reduce the possibility of injury. This analysis confirms the observation obtained from the work by Dell [2].



Figure 4  
Luggage unloading from Airbus A319 without the use of a conveyor.

Although available at the airport, the conveyor was not employed during this operation. Even though

it is not possible to state the exact reason why the equipment was not used, some considerations can be made. By the time the aircraft landed, other aircraft of the same company was still being loaded or unloaded. A new team had to be quickly move to the operation. This team arrived at the scene after the aircraft had already parked causing some delay of the unload. It is also observed that the team arrived with conveyor and baggage cart.

Before being able to position the conveyor, the ground worker, while opening the luggage compartment, was approached by another employee requesting her bag. To faster respond to the request, the worker moved the luggage cart under the aircraft, so he could climb up and retrieve the baggage requested. The procedure, without employing the conveyor, speeded up the removal of the employee's bag, however turned out to change the dynamics of the task to be performed.

It is worth noticing the difference in uniform between this worker and the one involved in Case 1. This difference, in principle, may point out a shift of the original role of the worker involved in the task.

#### 4.3. Case 3

This Case focuses on the removal of luggage from a Boeing 737-800. Just as the previous Case, the unloading was carried out without the use of a con-

veyor. When compared to the Airbus A319, the access door of Boeing 737-800 to the luggage compartment is located at a lower height. For this reason, even not employing the use of a conveyor the worker has no need climb up the baggage cart to pull the bags. He can remain on the ground (Figure 5).



Figure 5  
Luggage unloading from Boeing 737-800  
without the use of a conveyor.

Similar to previous cases, the time spent per bag was 2.28 seconds, with the worker spending less than 2 seconds to return to his original position. Thus, he performs 14 shipments per minute, an extremely high frequency of repetition.

Even ignoring the FM parameter, the LI values at the origin and destination remain high, approximately 2, as shown in Table 1. Because of the shorter distance between the baggage compartment and the ground, the LI values for the task developed with the Boeing 737 are smaller than those found for the Airbus, but still above the considered appropriate values.

It should be highlighted that although the lower height of the baggage compartment allows to, in practice, to dispense the conveyor, the use of this equipment would likely reduce the LI values in this Case, close to the ideal.

#### 4.4. Case 4

This Case illustrates the loading of a Boeing 737-800. Just as during the unloading the conveyor was not employed (Figure 6).

In this situation, the “LI at the origin” value is 1.47 (Table 1), which, even representing risk, shows an improvement compared to previous cases. The explanation for this improvement lies on the factors of horizontal displacement and torsion. Given that the worker stayed on the ground retrieving the baggage located on the cart he could come closer to the load,

reducing the horizontal distance. In addition, when using the front of the cart, the worker raises the bags from the front, without creating an angle of asymmetry.

The fact that the baggage cart used had closed sides induces the lifting of the bags from the front, avoiding the formation of an angle of asymmetry, as occurs in carts with sideways open.



Figure 6  
Luggage loading at Boeing 737-800  
without the use of a conveyor.

The improvement seen at the “LI at the origin” is not reflected at the destination which remains high. This is because the employee has to place the load directly into the aircraft, to a certain height from the ground. Once more, using the conveyor would help to reduce the risk of injury.

The conveyor would employ little or no influence on the LI at the origin, but would strongly reduce the LI at the destination to the extent that the worker would not need to move the load vertically.

#### 4.5. Case 5

The previous cases analyzed the load and unload of luggage from two major airline companies in the country on extremely important domestic routes. The aircrafts Airbus A319 and Boeing 737 are among those used in the Brazilian domestic flights. Case 5 evaluates the loading of a smaller aircraft, the Embraer 145. This national manufacturing aircraft is often employed by regional airlines. The flight load operation which is measured here had as destination Uberlândia, Minas Gerais.

The time spent per bag was only 1.17 seconds, with the worker spending about 1 second to return to his original position. With this rhythm, 27 shipments would be made per minute. That is, the double the number of shipments made by workers in the previous cases. On the one hand the total time needed

for the task is reduced, on the other hand the frequency of repetitions becomes extremely problematic. The high rate of repetition was obtained thanks to the dynamics of labor employed. The luggage is removed from the cart and passed, laterally, from one worker to the next. Figure 7 provides a better understanding of the task performed.



Figure 7  
Luggage loading at Embraer 145  
without the use of a conveyor.

Even disregarding the frequency, the LI found in this case is significantly worse than the others (Table 1). It is possible to understand this poor performance evaluating the factors that compose the equation RWL. The horizontal movement was greatly limited due to the dynamics of labor employed, where the luggage is passed from one worker to the next. Both need to reach out the arms to facilitate the work, raising the horizontal movement. In addition, there is a high asymmetry. The worker needs to bend laterally to receive the load, contributing to a worsening of parameter LI.

Finally, the vertical displacement at the destination was so high that the factor VM from Eq. (1) becomes zero, resulting RWL of the destination equal to zero and LI leading to infinite. This reveals that the worker had to promote a high lift of the luggage. The Embraer 145 features a small distance between the fuselage and the ground, however the luggage compartment door is located at the aircraft's tail. This region must be away from the ground to avoid collision during takeoff and landing operations (tail strike). Thus, although the aircraft fuselage is close to the ground and can induce an apparent advantage to ground work, this benefit is not confirmed in the case of luggage compartments located at the aircraft's tail.

## 5. Conclusions

From the study made it is possible to draw conclusions and recommendations in a practical point of view that, if adopted, would have the potential to reduce not only the risk of injury for the worker involved but also the costs for the companies with the absence of injured employees. It is also possible to conclude that the NIOSH methodology gives substance to the observations drawn from interviews with employees from this industrial sector [2].

The methodology showed that there is a clear need to reduce the frequency of lifts per minute, given that this was shown to be extremely high in all cases analyzed. The need to decrease the speed in which the task is performed was associated for more than 65% of the employees in this industry as being relevant to the reduction of back injuries [2]. It is possible to reduce the rate of repetition allocating a greater number of employees for the same task, since each employee performs the full transfer of each load. The passage of bags between them may contribute to further increase the risk of this activity.

Although in practice it is possible that the load and unload is developed without the conveyor, the use of this equipment proved to be a key factor to improve the LI parameter. According to Dell [2], 84% of the workers associate the task of transferring the luggage from the cart directly to the aircraft compartment as being a cause of back injuries. However, only 66% of them believe that the transfer from the cart to the conveyor may be associated with injuries. The cases here analyzed confirm the common sense.

Finally, the use of luggage carts with sides and top closed contribute to reduce the risk of injuries. These carts require the employee to remain on the ground while performing the operation, eliminating the risk of falls and reducing the vertical displacement. It also avoids the removal of bags from the side, promoting a twist. These recommendations, although do not have the power to eliminate the risk of injury while developing the task, would be able to significantly improve the working conditions, helping to reduce the number of absences and the costs involved.

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